DOCUMENT RESUME

ED 296 566 EC 210 336

AUTHOR Fitterman, L. Jeffrey
TITLE The Design of a Computer Table for the Physically Handicapped Student.
PUB DATE Mar 88
NOTE 59p.; Paper presented at the Annual Convention of the Council for Exceptional Children (66th, Washington, DC, March 28-April 1, 1988).
PUB TYPE Speeches/Conference Papers (150) -- Reports - Descriptive (141)

EDRS PRICE MF01/PC03 Plus Postage.
DESCRIPTORS *Computers; *Design Requirements; *Furniture Design; *Physical Disabilities
IDENTIFIERS *Computer Tables

ABSTRACT

The paper describes the development of a computer table for physically handicapped students including persons with moderate to severe cerebral palsy, muscular dystrophy, uncontrolled epilepsy, and paralysis due to physical trauma. The project first reviewed furniture currently available for the physically handicapped and then conducted ergonomic research concerning the design of a computer table for the target population. Also considered were the types of wheel chairs (Amigo, manual driven, electric motor driven) and the physical characteristics of each chair in terms of door clearance, wheel height, arm rest clearance, etc. A pilot study was conducted during a summer school computer literacy class for the physically handicapped to determine the physical access problems encountered by the students and teachers. The final design of the table incorporated the previous research. The paper includes shop drawings, specifications, and design criteria at each decision point. The resulting design is defended in light of the systematically identified criteria. Appendixes provide data on tools needed for production, wood materials needed, hardware needed, and costs of hardware and materials (total cost $289.74). (Author/DB)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

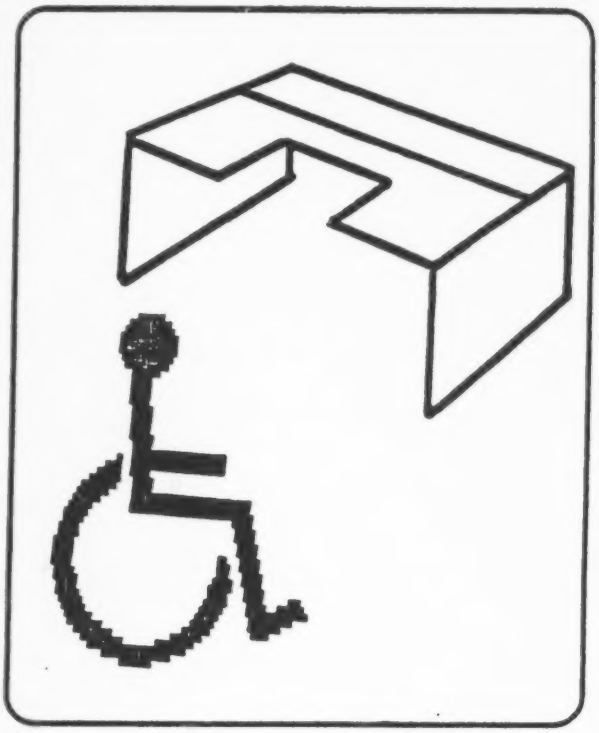
☑ This document has been reproduced as received from the person or organization originating it.

☐ Minor changes have been made to improve reproduction quality.

• Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

ED296566

THE DESIGN OF A COMPUTER TABLE FOR THE PHYSICALLY HANDICAPPED STUDENT



L. JEFFREY FITTERMAN, ED.S.

FDLRS/TECH-12

TAMPA, FLORIDA

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY

L. Jeffrey Fitterman

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

BEST COPY AVAILABLE

EC 210 336

Paper presented at the Annual Convention of the
Council for Exceptional Children
(66th, Washington, DC, March 28-April 1, 1988)

© Lawrence Jeffrey Fitterman 1986
All Rights Reserved

Important Note: To retain the original integrity of the computer table table design the materials, measurements, and assembly procedure must be strickly followed.

L. Jeffrey Fitterman, Ed.S.
Florida Diagnostic and Learning
Resources System
Hillsborough County Public Schools
411 E. Henderson Avenue
Tampa, Florida 33602
(813) 272-4555
SunCom 547-4555

TABLE OF CONTENTS
CONTINUED

COMPUTER TABLE TOP ADJUSTMENT SCHEME 24

DESIGN SUPPORT OF ADJUSTMENT SCHEME 25

HARDWARE AND ASSEMBLY 25

CHAPTER FIVE

STRUCTURAL ANALYSIS 28

TIPPING ANALYSIS 28

HINGED COLLAPSE 31

LOAD ANALYSIS 32

RE-EVALUATION OF DESIGN 34

SELECTED REFERENCES 36

APPENDIXES 37

1 - TOOLS NEEDED FOR PRODUCTION 38

2 - WOOD MATERIALS NEEDED FOR PRODUCTION 39

3 - HARDWARE NEEDED FOR PRODUCTION 40

4 - ESTIMATED COST FOR PRODUCTION 41

5 - PRODUCTION TIME 43

SHOP DRAWINGS 44

TOP VIEW OF COMPUTER TABLE DESIGN 45

FRONT VIEW OF COMPUTER TABLE DESIGN 46

SIDE VIEW OF COMPUTER TABLE DESIGN 47

ADJUSTMENT SCHEME OF COMPUTER TABLE DESIGN 48

TABLE OF CONTENTS

LIST OF TABLES vi

LIST OF FIGURES vii

ABSTRACT viii

CHAPTER ONE

INTRODUCTION 1

PURPOSE 2

DEFINITION AND DELIMITATIONS 3

CHAPTER TWO

DESIGN CONSIDERATIONS 5

ERGONOMIC FACTORS 6

CHAPTER THREE

PROCEDURE 11

CHAPTER FOUR

ROUGH DESIGN 13

COMPUTER/USER TABLE TOPS 13

COMPUTER TABLE TOP 15

USER TABLE TOP 17

COMPUTER TABLE SUPPORT LEGS 20

TABLE TOP ADJUSTMENT SCHEMES 22

USER TABLE TOP SUPPORT 22

USER TABLE TOP ADJUSTMENT SCHEME 23

COMPUTER TABLE TOP SUPPORT 23

LIST OF TABLES

TABLE 1	-	Measurements of Computers With Detachable Keyboards	15
TABLE 2	-	Measurements of Computer Monitors	16
TABLE 3	-	Measurements of Torso Width in Inches	18
TABLE 4	-	Measurements of Detachable Keyboards	20
TABLE 5	-	Total weight of the wood	29

LIST OF FIGURES

FIGURE 1 -	Frontal table access	10
FIGURE 2 -	Three-quarter view of computer/user table tops	14
FIGURE 3 -	Three-quarter view of computer support legs	21
FIGURE 4 -	Free body diagram	29
FIGURE 5a -	Hinged collapse - condition of force applied/ before	31
FIGURE 5b -	Hinged collapse - condition of force applied/ after	31
FIGURE 5c -	Hinged collapse - general cross bracing	31
FIGURE 6 -	Flexural stress for worst case	32
FIGURE 7 -	Top view of computer table design	45
FIGURE 8 -	Front view of computer table design	46
FIGURE 9 -	Side view of computer table design	47
FIGURE 10 -	Adjustment scheme of computer table design	48

8

A COMPUTER TABLE FOR THE PHYSICALLY HANDICAPPED

by

Lawrence Jeffrey Fitterman

An Abstract

This project has as its target population the physically handicapped with special emphasis on the non-ambulatory. The population consists of those individuals with moderate to severe cerebral palsy, muscular dystrophy, uncontrolled epilepsy, and paralysis due to physical trauma. The project's purpose is to design a computer table for the defined target population. At the current time, the physically handicapped experience much difficulty in using existing furniture. The design enhances the target population use of computers to extend their abilities. A review of the literature featuring furniture for the physically handicapped has not revealed a computer table specifically designed for the defined target population. The project first addresses furniture currently available for the physically handicapped and then addresses the ergonomic research concerning the design of a computer table for the target population. Next, the project addresses the types of wheel chairs (Amigo, manual driven, electric motor driven operation) and the physical characteristics of each chair in terms of door clearance, wheel height, arm rest clearance, etc. Through observation and interview, a pilot study was conducted during a summer school computer literacy class for the physically handicapped at a local high school to study the physical access problems encountered by the students and teachers.

Lastly, the project develops the design for the computer table incorporating aforementioned research. Shop drawings are developed so that the structural integrity and ergonomic factors of the completed design can be evaluated. Criteria for the design is clarified at each decision point and the resulting product is defended in light of the systematically identified criteria.

Abstract approved: Gary W. Tubb

Major Professor: Dr. Gary Tubb

3/12/86

Date of Approval

CHAPTER ONE
INTRODUCTION

According to The 1983, President's Committee on Employment of the Handicapped, an estimated one out of ten persons in the United States has limited mobility due to a temporary or a permanent physical handicap. These individuals are either ambulatory--physically mobile but with some physical limitations--or non-ambulatory--relying on some other means for mobility. This project is designed to aide the non-ambulatory segment of the overall target population, known as the physically handicapped, in the use of computers.

At this time, the furniture for these individuals is in the form of desks, tables, and other household furniture and fixtures that are designed for the non-handicapped and then modified for use by the physically handicapped..

PURPOSE

A rapidly increasing awareness of the enhanced potential offered handicapped persons through the use of micro and mini-computers has indicated the need for the development of a unique computer table designed to accommodate the special requirements of this target group. Some special needs are: 1) higher and wider table clearances for the wheel chair user, 2) restraints for stabilizing the unwanted body movements of the user, and 3) sturdier construction. Through the use of such a table design, more handicapped individuals will be able to access a computer to enhance and extend their abilities that otherwise would go untapped. The purpose of the project is to design a computer table for the target group and to test the design for strength and stability. The project clearly documents the systematic process of designing a computer table. Criteria for the design is clarified at each decision point and the resulting product is defended in light of the systematically identified criteria.

DEFINITIONS AND DELIMITATIONS

The following are definitions that are unique to this project.

1. Frontal table access is defined as area needed for the individual and his or her wheel chair to fit comfortably up to and under the table.
2. Restraints are defined as those straps and/or braces (foam rubber, metal, plastic) needed to control unwanted movements in the arms, forearms and hands.
3. Wheel locking devices are defined as those mechanisms used to stop any unnecessary forward, backward or lateral movements of the wheelchair.
4. Peripheral access is defined as the amount of area around the desk needed for docking by an individual in a wheel chair.
5. Ergonomics is defined as "developing systems with the dimensions which can be adapted to the variety of people expected to use them" (Yeaman,1983).

The following are delimitations that are unique to this project. The computer table:

1. is not to be permanently connected to any permanent structure such as walls or floors.
2. does not have any electrical outlets or wires connected to the table.
3. tops do not tilt and remain parallel to the floor at all times.
4. does not have any wheels connected to the table legs.
5. is designed for computers with detachable keyboards.

CHAPTER TWO
DESIGN CONSIDERATIONS

Designing a computer table for the physically handicapped individual requires precise planning and the ability to devise individual solutions for specific limitations. The designer should carefully consider the extent of the individual's disability.

To assume that the disability involves solely an impairment of the lower body can be a costly design mistake. As Saltman and Chasin (1984) point out, such factors as the strength and efficiency of one's grasp, the length of one's arm reach, and the direction and degree one's upper body can be bent should be determined before designing furniture. Alfred Jacobson, vice president of Rehab Associates - a consulting firm that designs and constructs housing specially for the handicapped - suggests that an important aspect in design approach "is the attention paid to the individual's needs and capabilities of the clients and their specific impairments." Jacobson's plans are devised after consulting with rehabilitation nurses, physical therapists, and occupational therapists. He emphasizes that "the best assistant a designer can have is the person for whom the work is intended. You have to get that person to function at the highest level of their capability. Every situation is

different and they're all learning experiences."

An important affective element to strive to incorporate into a design for the physically handicapped is that the design should be considered by the user as an immediate part of his or her environment. Thus, a successful computer table design will first meet specifications to accommodate many types of wheel chairs and their users and, secondly, include an innovative but simple design for physical adjustments to adapt to each individual handicapped user.

Many ergonomic factors should be addressed when designing computer tables for wheel chair access. Wheel chairs are prescribed for patients based upon ten main sections: caster diameter, chair size, frame type, special frame construction, arm style, drive, back style, heavy duty construction, foot and leg support, and wheel construction.

ERGONOMIC FACTORS

The following three sections are most important when designing computer tables for wheel chair access.

The first section is chair size. Chair size refers to the seat area. There are seven main chair sizes designed to accommodate the individual user. The chair sizes range from

an 18" width with a 16" depth for adults to a tiny tot size designed with a 12" width with an 11 1/2" depth. Thus, the width of the space between the computer table legs and the depth of the user computer table area must be defined to accommodate the above range of various wheelchair sizes.

The second section is frame type. There are three main types consisting of amputee, outdoor, and indoor frame styles. The amputee type has no leg frame. The outdoor style has leg restraints that consist of either a horizontal bar with a leg holding strap or a high-ground clearance leg restraint, and is a smaller version of the indoor leg restraint. The indoor frame consists of a bulky but sturdy vertical hung leg restraint such as ones attached to the wheel chairs used at hospital emergency rooms. Thus, the computer table must allow for the maximum 40 inch depth of the wheel chair with an indoor frame.

The third section is arm style. Arm rests range from armless to wrap-around, including other features such as adjustable, rotating, non-detachable, or detachable--as used on the sports model. The computer table must allow for the maximum 30 inch wheel chair height measured from the top of the arm rests to the floor.

Not only should the ergonomics of the general populace be considered, but the aforementioned three sections should be

considered if the computer table is to accommodate the target population in the use of microcomputers.

Consistent with the concept that the design will first accommodate many types of wheel chairs as well as adapt to specific requirements, as mentioned above, the following wheel chair measurements are a composite of maximum dimensions recorded from each type of wheel chair used during the pilot study:

- a maximum height of 30 inches measured from the floor to the top of the arm rests;
- a maximum width of 20 inches measured from the outside of the arm rests (Amigo chair) or a total maximum width of 27 inches (wheel chairs with horizontal propulsion levers on the hand wheels);
- a maximum length of 50 inches measured from the back of the wheels to the front leg rests, including an overlap for the feet and toes, and a maximum of 40 inches measured from the leg rests to the back rest of the seat.

Another important consideration when designing for this segment of the population is the physical placement of the designed furniture in the work room. The designed furniture will be totally useless if the designer does not take into account the minimum clearances needed by the target population to gain access to the furniture within the work

room. The physically handicapped individual, in a wheelchair (non-ambulatory), needs certain minimum clearances to use each piece of furniture.

The method used by individuals to access and dock with the computer table (peripheral access) involves the following steps: 1) approach parallel to either side of the table requiring a minimum clearance of 27 inches; 2) pass the table by one full length of the wheelchair requiring a minimum clearance of 50 inches; 3) make a slow turn around until the front of the wheel chair is perpendicular with the entrance site of the table; 4) move the chair to the table until in a comfortable position; 5) lock the wheels using the manual locks or by turning off the electric motor of the wheelchair (See FIGURE 1). With respect to a table design, radial measurement for access should be considered. The minimum turning area required is a radius of approximately 50 inches. This radius is measured as the maximum length of the wheel chair from the back of the wheels to the toes and/or leg rests of the individual's wheelchair.

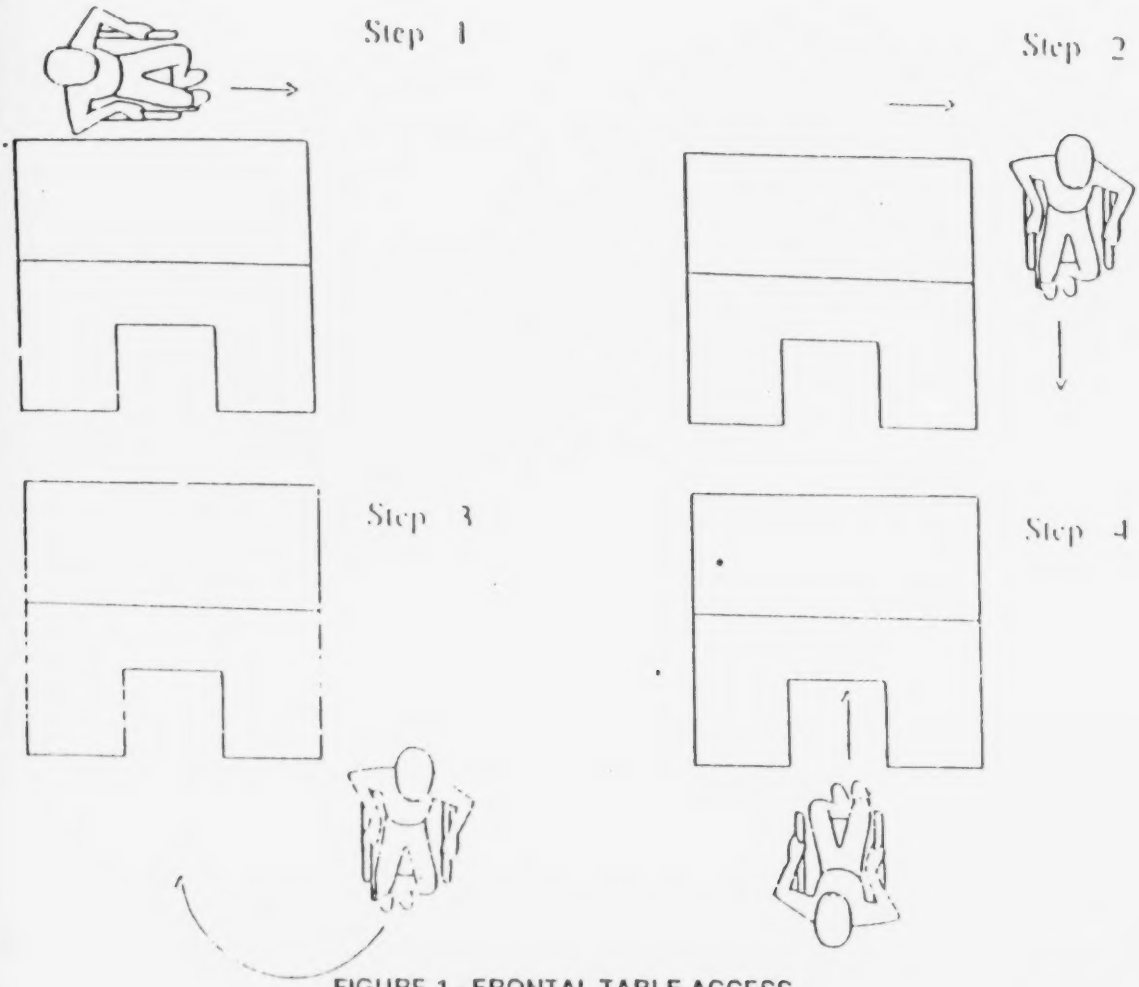


FIGURE 1 - FRONTAL TABLE ACCESS

CHAPTER THREE
PROCEDURE

The following text details the procedure for designing a computer table for the physically handicapped. First, a pilot study was conducted to gain valuable data through direct observations of physically handicapped individuals to conclude on what types of wheelchairs were used, minimal clearances needed and the ways these students accessed existing furniture. The pilot population consisted of eight high school students, varying in age from thirteen to sixteen years of age, confined to wheelchairs. The students' mental capabilities ranged from an IQ of 62 to an IQ greater than 136. Their physical disabilities included physical trauma due to automobile accidents, moderate to very severe cases of cerebral palsy, and moderate cases of muscular dystrophy and spina biffida. Of the above population, three students each had full use of their arms and hands, two students each had moderate use of one arm and hand with little or no use of the other arm and hand, and three students each had no usable limb coordination (forearms were in restraints). The last group used either a marker-like object placed between their teeth or a head band with a connected pointer for use as an input device. Five

students used the conventional indoor type wheelchairs, two students used sport type wheelchairs and one student used an Amigo wheelchair (electric cart with a conventional seat). Secondly, the data from the pilot study, as detailed in chapter two, was incorporated into the design.

The design procedure is divided into four sections. The first section includes the development of a rough design drawing based upon the pilot study and ergonomics. Secondly, the rough design was tested through the use of a structural design program (STRUDL - Structural Design Language) using an IBM PC/AT. This program simulated a physical test of the table's strength and stability under work loads. Thirdly, a re-evaluation of the design was conducted to reflect the synthesis of the program's test findings. Lastly, final shop drawings were developed, leading to the production of the actual computer table. The shop drawings include a list of materials, tools needed for production, production time projection and the estimated cost of production.

CHAPTER FOUR
ROUGH DESIGN

The rough design procedure is divided into four sections. The first section details the development of the computer table tops. The second section details the development of the computer table legs. The third section details the development of the computer table top adjustment scheme. The last section includes hardware and hardware positioning for table assembly.

COMPUTER/USER TABLE TOPS

The computer table is designed with two separate tops to ergonomically accommodate the need for adjusting the height of the work area independently from the need for adjusting the height of the video display. Each table top has rounded corners, and flat surfaces that will not tilt to prevent accidents that could otherwise be caused by collision with sharp corners and heavy objects sliding off the table tops onto the user.

The smaller back table top, termed the computer table top, supports the computer; and the larger frontal table top, termed the user table top, supports the computer keyboard and serves as the user's work area.

The exterior corners and interior angles of the table are rounded to reduce any chance of a physical injury to the user.

Both computer table tops are composed of 1 inch solid wood. Solid wood is recommended because of its strength and endurance (Ramsey & Sleeper, 1970).

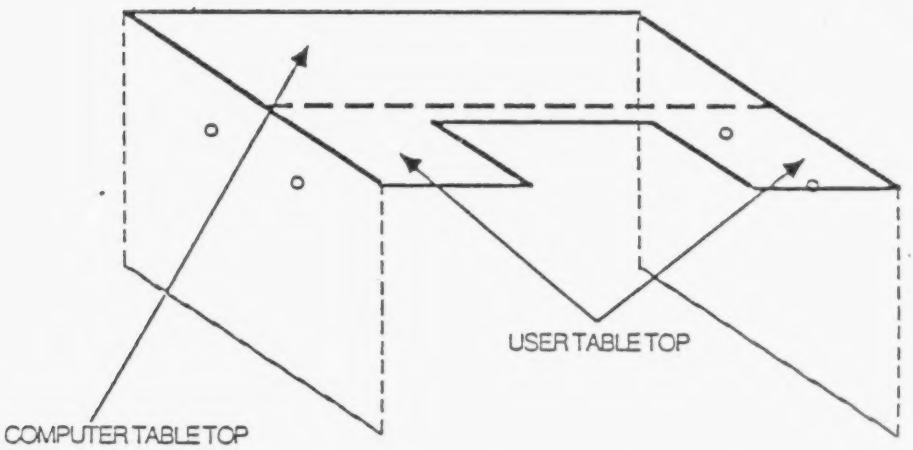


FIGURE 2 - THREE-QUARTER VIEW OF COMPUTER TABLE TOPS

COMPUTER TABLE TOP

The computer table top is designed to accommodate the maximum depth, width and length of microcomputers with detachable keyboards (See Table 1). The data derived from Table 1 concludes that the minimum and maximum depths of 8.00 to 16.00 inches are needed to accommodate all current microcomputers. The minimum and maximum widths and heights do not prove to be critical in the design because of the 48 inch width and the computer work area's height adjustability.

TABLE 1
MEASUREMENTS OF COMPUTERS WITH DETACHABLE KEYBOARDS

COMPUTER	DEPTH	WIDTH	HEIGHT
IBM PC/XT	16.00 inches	19.00 inches	5.50 inches
IBM PCjr	11.00 inches	13.75 inches	4.00 inches
TANDY 1000	13.25 inches	16.00 inches	5.75 inches
COMMODORE 64	8.00 inches	16.00 inches	2.25 inches
APPLE-MACINTOSH	12.00 inches	9.50 inches	16.00 inches

The depth of the table top not only accommodates the computer but allows a range for viewing the monitor from a minimum depth of 10.50 inches to a maximum of 16.50 inches (See Table 2). The data derived from Table 2 concludes that

the minimum and maximum depths of 12.00 and 15.50 inches for computer monitors fit within the tolerance range of the computer area of 10.50 to 16.50 inches.

The minimum tolerance range is figured by adding the 10 inches of the computer work area that houses the keyboard to the .50 inch of the space between the tables. The maximum tolerance range is figured by subtracting the minimum depth of a computer monitor (12.00 inches) from the 18.00 inch depth of the computer table top (See Figure 7).

TABLE 2
MEASUREMENTS OF COMPUTER MONITORS

MONITOR	DEPTH	WIDTH
IBM PC/XT (RGB)	15.00 inches	15.00 inches
IBM PCjr (RGB)	15.00 inches	14.00 inches
IBM PC/XT (MONOCHROME)	12.00 inches	14.75 inches
TANDY CM-2 (RGB)	13.25 inches	16.00 inches
COMMODORE 1702 (COMPOSITE)	15.50 inches	14.50 inches
APPLE/MACINTOSH	12.00 inches	9.50 inches
AMDEK COLOR I (COMPOSITE)	16.00 inches	15.00 inches

USER TABLE TOP

The user table top measures 24 inches in depth by 48 inches in width. One of the main premises in the design of this computer table is that the user should feel as if he/she is part of his/her immediate environment. With this premise in mind, a cut-a-way is designed into the user work area. This cut-a-way area, in which the user docks, measures 16.50 inches in width by 14 inches in depth.

To determine the dimensions of the cut-a-way area, individuals, ranging in age from 11 to 37 years old and randomly selected from a junior and senior high school and a college, were measured for torso width and the results compiled in Table 3. The data in Table 3 concludes that the minimum and maximum torso widths, measured at the bottom of the rib cage, are 8.50 and 14.00 inches. The 16.50 inch width of the cut-a-way area accommodates a maximum torso width of over 16 inches which is well within the average torso width of 10 to 15 inches. The 14 inch depth of the cut-a-way accommodates any user including a user with a torso brace (See Table 3).

TABLE 3
MEASUREMENTS OF TORSO WIDTH IN INCHES

GENDER	AGE	WIDTH	WAIST
F	11	9.50	27.00
F*	16	14.00	39.50
F	17	10.00	28.00
F	21	9.00	27.00
F	27	8.50	24.00
F	32	11.00	30.00
F	33	10.00	29.00
	==	=====	=====
AVERAGE	22	10.29	29.21

* denotes individual with torso brace

GRAPH OF TABLE 3

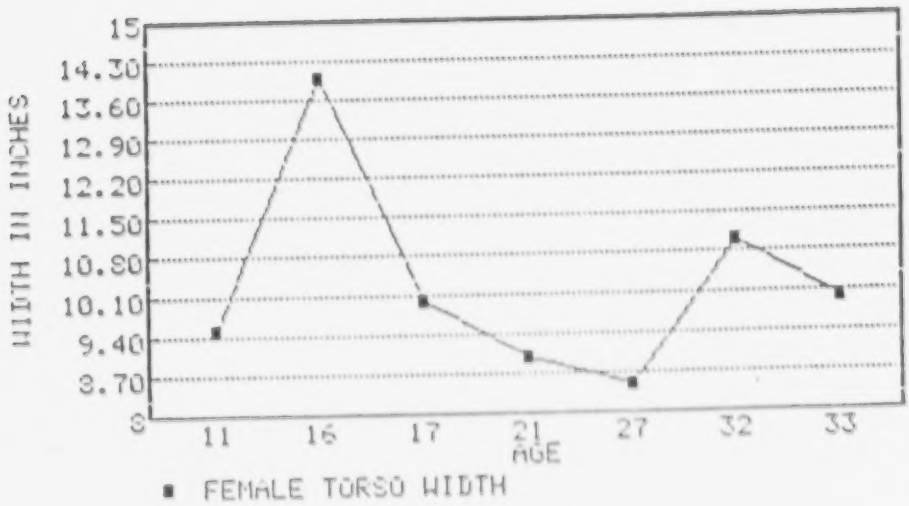
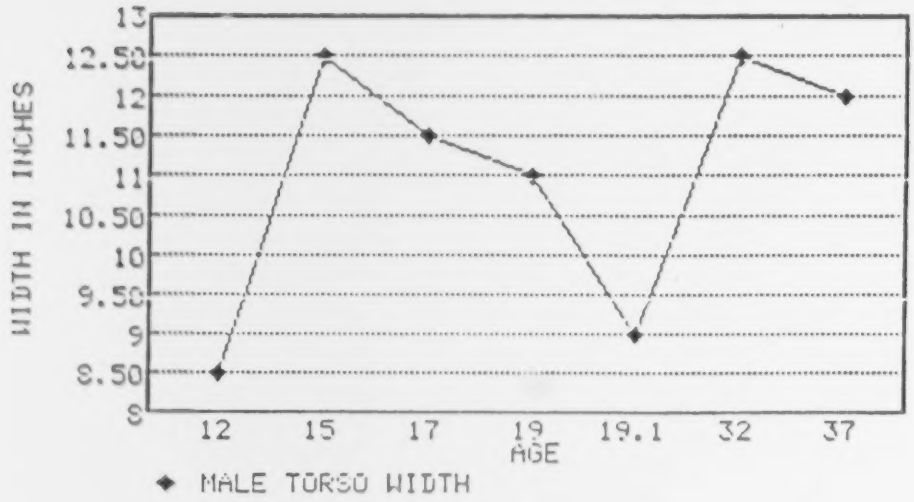


TABLE 3
MEASUREMENTS OF TORSO WIDTH IN INCHES

GENDER	AGE	WIDTH	WAIST
M	12	8.50	22.00
M	15	12.50	34.00
M*	17	11.50	34.00
M	19	11.00	27.00
M	20	9.00	26.00
M	32	12.50	34.00
M	37	12.00	34.00
	==	=====	=====
AVERAGE	22	11.00	30.14

* denotes individual with torso brace

GRAPH OF TABLE 3



A rectangular work area of 15.75 inches by 24 inches remains on either side of the cut-a-way. The remaining 10 inch area in front of the cut-a-way accomodates the computer keyboard (See Table 4). The data derived from Table 4 concludes that the minimum and maximum clearances needed to accommodate the keyboard are 5.75 and 8.00 inches. This clearance is well within the 10 inch tolerance range.

TABLE 4
MEASUREMENTS OF DETACHABLE KEYBOARDS

KEYBOARD	DEPTH	WIDTH
IBM PC/XT	7.50 inches	19.00 inches
IBM PCjr	6.50 inches	13.50 inches
TANDY 1000	7.75 inches	16.00 inches
COMMODORE 64	8.00 inches	16.00 inches
APPLE-MACINTOSH	5.75 inches	13.25 inches

COMPUTER TABLE SUPPORT LEGS

The computer table tops are supported by two main 1 inch thick solid wood rectangular support legs measuring 26 inches in height by 40 inches in width (See Figure 9). The height of the support leg accommodates the minimum clearance of 24 inches needed by any type of wheelchair. The width of

the support leg is computed by adding the depth of the table tops, plus the .50 inch space between the table tops, then subtracting a 1.25 inch overhang across the front and back of the computer table tops (Ramsey & Sleeper, 1970). Along bottom of each support leg two 1 inch by 2 inch by 40 inch runners that are connected to give added lateral and vertical support (See Figure 10). Recessing the support legs increases the ability to handle and adjust the table tops.

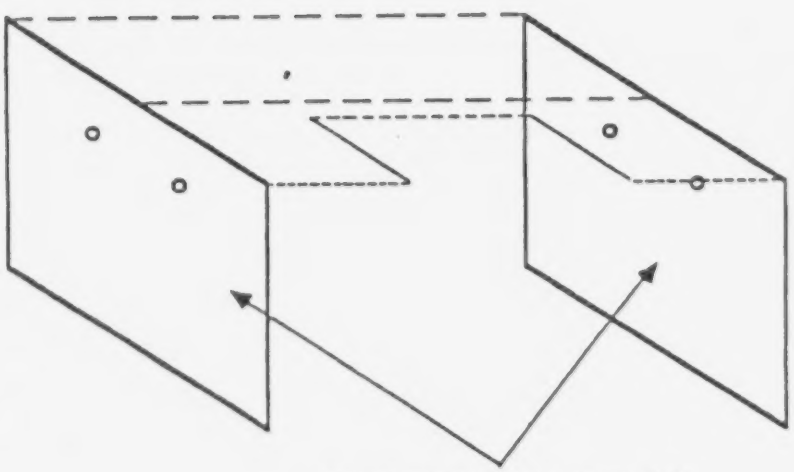


FIGURE 3 - THREE-QUARTER VIEW OF COMPUTER SUPPORT LEGS

increases the ability to handle and adjust the table tops.

TABLE TOP ADJUSTMENT SCHEMES

The adjustment scheme is divided into the adjustable table top supports for both table tops and the placement and design of the adjustment holes.

USER TABLE TOP SUPPORT

This adjustable support is designed to support the user work area table top, to connect the table top to the computer table legs, and to adjust the height of the table top. The support measures 22 inches in width by 13 inches in height by 1 inch thickness (See Figure 9 & 10). The adjustable support has two 1 inch by 1 inch by 22 inch stops that run the width of the support (See Figure 9). These stops connect to the table top and the adjustable support. The stops are also added to the design to both increase the stability of the table top and to act as a physical stop in case the table is inadvertently dropped onto the computer legs. Otherwise, if the table top is dropped, the possibility of weakening the connection between the table top and the support and thus the stability of the table can

occur. At rest, the user work area table top surface is two inches above the computer legs, 26 inches above the floor and has a user clearance of 25 inches from the floor to the bottom of the user work area table top.

USER TABLE TOP ADJUSTMENT SCHEME

The user work area table top is designed to adjust at increments of 2 inches. The 3/8 inch holes are drilled through the table top support, beginning at 3 inches below the bottom of the table top and then every 2 inches to a depth of 11 inches (See Figure 9 & 10). Drilling more holes at less of an increment would weaken the integrity of the the table top supports (Ramsey & Sleeper, 1970). This arrangement allows the user table top to adjust from a minimum height of 26 inches to a maximum height of 34 inches above the floor, based upon minimum and maximum wheelchair clearances (See Page 8).

COMPUTER TABLE TOP SUPPORT

The adjustable computer table top support is designed to support the computer table top, connect the table top to the computer table legs, and adjust the height of the table top. The support measures 16 inches in width by 16 inches in height by 1 inch thickness (See Figure 9 & 10). The

adjustable support has two 1 inch by 1 inch by 16 inch stops that run the width of the support. These stops are designed to connect to the table top and the adjustable support. The stops are also added to the design both to increase the stability and to act as a physical stop in case the table is inadvertently dropped onto the computer legs. At rest, the computer table top is two inches above the computer legs, 26 inches above the floor, and has a user clearance of 25 inches between the floor and the bottom of the table top.

COMPUTER TABLE TOP ADJUSTMENT SCHEME

The computer table top is designed to adjust at variable increments of 2, 3, 2, 2, and 3 inches. The 3/8 inch holes are drilled beginning 3 inches below the bottom of the table top and then 3, 2, 2, and 3 inches to a depth of 13 inches (See Figure 9 & 10). Drilling more holes at less of an increment would weaken the integrity of the the table top supports (Ramsey & Sleeper, 1970). This allows the computer table top area to adjust from a minimum height of 26 inches to a maximum height of 39 inches above the floor, based upon minimum and maximum wheelchair clearances (See Page 8).

DESIGN SUPPORT OF ADJUSTMENT SCHEME

The design scheme is based on the sound ergonomic research that the center of the computer's video display should be 3 inches above the keyboard (M. Helander, 1982). In support of the aforementioned research, the computer table top assembly, which consists of the support and the computer table top, should be adjusted to the second adjustment hole and the user work area table top assembly should be at rest in the first hole (See Figure 9). If the user work area assembly is raised to the next level, the computer table top assembly can be raised to its next corresponding hole to maintain the 3 inch differential. Users must also take into consideration the monitor and computer unit's height when at rest on the computer table.

HARDWARE AND ASSEMBLY

The computer table is assembled in four phases. The first phase involves the assembly of the runners to the table support legs and the table top supports. The second phase involves the attachment of the table top supports to the table tops. The third phase involves the attachment of the table top support assembly to the table support legs. The

last phase involves the attachment of the back support to the computer table assembly (See Appendix 1-5).

In the first phase, the runners to the table support legs and the table top supports are connected by wood glue (aliphatic resin; a strong, fast setting, heat and water resistant glue for working with wood); and held in place by adjustable wood clamps for a period of 30 minutes (See Appendix 1). Additional, 1 1/4 inch finishing nails will be driven every 4 inches to insure that there is no later separation (See Appendix 3). In the second phase, the table top supports are connected to the table tops by 2 inch long by 1/4 inch in diameter flat head screws (See Appendix 3). The pilot holes for these screws are counter sunk to avoid exposed surface metal. The pilot holes on the computer table top are placed every 4 inches as shown in Figure 7. The pilot holes on the user table top are be placed every 5 1/2 inches as shown in Figure 7.

In the third phase, the table support legs, one at a time, are rested on their back edges (See Figure 9) and held in a vertical position. The table top assemblies are then attached to the first table support leg with the use of a 2 1/2 inch long by 3/8 inch in diameter stove bolt (See Appendix 3). The head of the stove bolt faces toward the outside of the table and is flush with the surface of the computer table legs. Recessing the head of the

stove bolt into the wood only succeeds in weakening the structural integrity of the computer table legs. The computer support leg and table top assembly are assembled through the existing holes as shown in Figure 10. The two pieces are held in place by a 3/8 inch flat and lock washer and a 3/8 inch hexagon nut (See Appendix 3). The table top assemblies are attached to the second table support leg in the same manner.

In the last phase, the 44 by 22 by 3/8 inch back brace is attached to the back of the table support legs with the use of 2 inch long by 1/4 inch in diameter flat head screws (Appendix 2-3). The pilot holes for these screws are counter sunk so that there is no exposed surface metal and needless obstacles that can produce potential hazards and inconveniences. Examples of such hazards and inconveniences are scratches to the user's body from exposed metal and the inability to lay books and papers flat on the table tops. The pilot holes are drilled starting 3 inches from the top of the back brace and then every 4 inches as shown in Figure 7.

The complete computer table has no reinforcing cross-bars to interfere with the docking of the user to this computer table. The computer table may be sanded, stained and painted with polyurethane to give a smooth exterior surface.

CHAPTER FIVE
STRUCTURAL ANALYSIS

The structural analysis of the computer table is divided into three structural tests. The first analysis tests the structural concept of tipping. The second tests the structural concept of hinged collapse. The last analysis tests the concept of flexural stress from various loads.

Tipping Analysis

1. Tipping is a structural phenomena that can occur for this table when the table top is struck with a horizontal force at the operator opening. The following five assumptions are made concerning this table and the phenomenon of tipping:

    1. Dead load (weight of hardware and table) Hardware = 30 lbs.
    2. Back of table is secured at the floor to prevent sliding.
    3. Centroid (center of gravity) of the table is centered in all three dimensions.
    4. Average height (due to adjustable top) is 30 inches.
    5. The unit of weight for red oak wood is 47 lbs./cu.ft.

The volume of the wood is necessary to find the total weight of the table alone. The total weight of the table is figured by multiplying the sum total volume of all wood table parts in cubic feet (3.50 cu.ft.) by the weight (lbs.) of the wood per cubic foot (47 lbs./cu.ft.).

TABLE 5
THE TOTAL WEIGHT OF THE WOOD

1. Computer top:	18" X 48" X 1" = 0.50 cu.ft.
2. Desk top:	
(24" X 48" x 1") - (16 1/2" X 14" X 1")	= 0.53 cu.ft
3. Back:	22" X 44" X 1" = 0.56 cu.ft.
4. Slides (2):	(22" X 40" X 1")2 = 1.02 cu.ft.
5. Computer top legs (2):	(16" X 15" X 1")2 = 0.28 cu.ft.
6. Desk top legs (2):	(22" X 13" X 1")2 = 0.33 cu.ft.
7. Computer top stops (4):	(1" X 1" X 16")4 = 0.04 cu.ft.
8. Desk top stops (4):	(1" X 1" X 22")4 = 0.05 cu.ft.
9. Floor braces (4):	(1" X 2" X 40")4 = 0.19 cu.ft.
TOTAL VOLUME OF WOOD	= 3.50 cu.ft.
TOTAL WEIGHT OF WOOD	= 164.50 lbs.

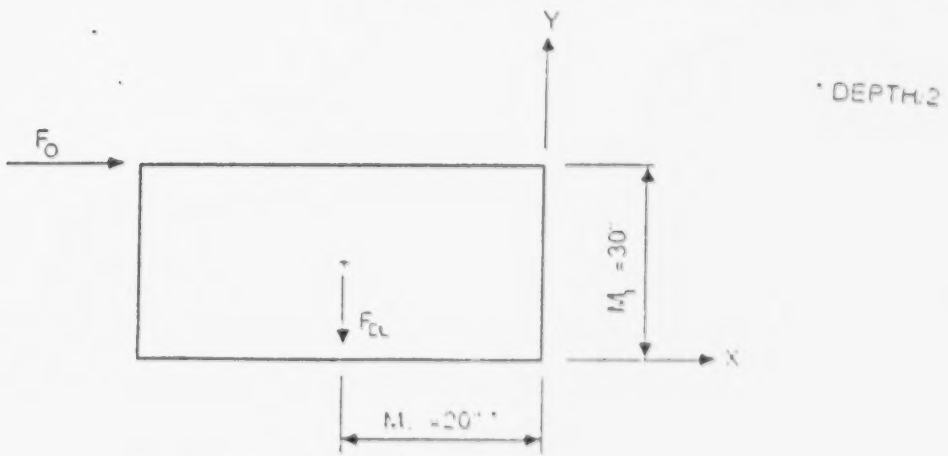


FIGURE 4 : FREE BODY DIAGRAM

F_O = Force against table by the operator

F_{DL} = Dead load weight (wt. of table and hardware)

M_1 = Average height

M_2 = Depth of the table divided by 2

Definition of the Moment of the Force- Tipping occurs when:

$$F_O (M_1) > F_{DL}(M_2)$$

$$F_O > \frac{F_{DL}(M_2)}{M_1}$$

$$F_{DL} = 3.50 \text{ C.F. } (47 \#/\text{C.F.}) + 30 \text{ LBS.} = 194.5 \text{ IBS.}$$

$$F_O > \frac{194.5 \# (20")}{(30")} > 130\#$$

Therefore, as long as the user does not exert a horizontal force in excess of 130 lbs. against the table, under the aforementioned conditions, the table does not tip.

Hinged Collapse

Hinged collapse is a phenomenon common in a simple frame as shown below when a sideways force is exerted.

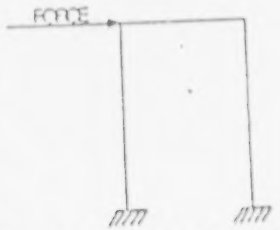


FIGURE 5A - HINGED COLLAPSE CONDITION BEFORE FORCE APPLIED

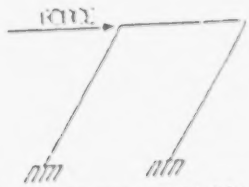


FIGURE 5B - HINGED COLLAPSE CONDITION AFTER FORCE APPLIED

To prevent this, generally cross bracing is provided:

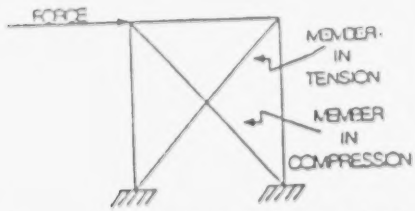


FIGURE 5C - GENERAL CROSS BRACING

As the solid members (top, sides and back) provide the same support as the typical cross bracing, the hinge failure cannot occur unless a force is exerted which either buckles the wood panels or the screwed connections fail. Due to the function or purpose of this table, this condition is highly improbable.

Load Analysis

Load analysis is the maximum flexural stress determined for a worst case load on the desk top. The following four assumptions are made concerning this table and the phenomenon of load analysis:

1. Dead load -
   a) computer/keyboard - 30 lbs.
   b) monitor - 30 lbs.
   c) miscellaneous equipment - 25 lbs.
   d) manuals and books - 15 lbs.

Estimated maximum dead total load is 100 lbs.

Young's Modules of Elasticity:

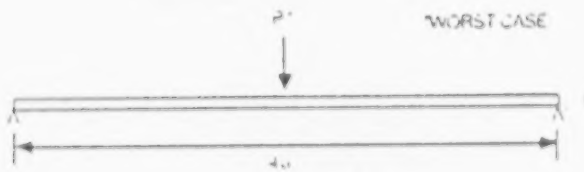


FIGURE 6 - FLEXURAL STRESS FOR WORST CASE

Where $\bar{y}$ = the centroid axis

$$I = 1.12\,bh^3 = 1.12\,(48")(1")^3 = 4^{-4}$$

$$M = \frac{PaD}{I} = 100\#(24")^2 = 1200\ in\ lbs$$

$$\Sigma\ \frac{M\bar{y}}{I} = \frac{1200\ in\ lbs\ (0.5")}{4^{-4}} = 150\ psi$$

Therefore, under the worst conditions, the table top resists a bending of 150 psi. which is greater than the estimated load.

Check for maximum load in the table supports for buckling:

The effective slender ratio:

$$(kl/r)_o = \frac{(1)30"}{\frac{1.6}{2\sqrt{3}}} = 6.49$$

Where:

k = 1 · pinned · pinned

r = radius of gyration

$$r = \sqrt{I/A}$$

The least value of (kl/r) for which Euler's formula remains valid is: assume proportional limit, 4.6×10^3 psi., for red oak.

$$(kl/r)_o = \sqrt{\frac{\pi^2 E}{\Sigma_{pl}}} = \sqrt{\frac{\pi^2 (1.5 \times 10^6)}{4.6 \times 10^3}} = 56.73$$

For Euler's column formula to be valid:

$$\Sigma_{cr} > \Sigma_{pl} \longrightarrow (kl/r)_x > (kl/r)_o$$

Since this is not the case, the sides of the desk fall into the category of short columns. Short columns have a high tolerance for buckling (refer to section on Hinged Collapse). The table top is be the controlling factor on any failure due to loading.

RE-EVALUATION OF DESIGN

Through informal interviews with the target population and their educational counterparts; at an area high school, a major vocational education center, an area college, and an educationl conference, the concept of table restraints for restricting unwanted body movements was deleted from the design. The interviewed potential users see the concept of the table restraints as unwarranted for the following reasons:

1. upper limb restraints can be integrated with wheelchairs.
2. restraints are viewed as a personal affront to the users' dignity.
3. users can control their own movements.
4. users can rest their upper limbs on the user table top work areas limiting most of the unwanted movements.
5. physical limitations prohibit some users from placing their upper limbs on the table top to use the restaints.

The synthesis of the aforementioned structural testing has concluded that no design changes are necessary and that the design does not exhibit any safety hazards due to normal stress as concluded in the following data:

1. Tipping occurs only if a horizontal force of greater than 130 lbs. of force -is applied to the user's opening in the user desk top. If the table is pushed flush against the wall, tipping is improbable.

2. Hinged collapse is highly improbable because of the design incorporating a top, side and back. Also, it is very unlikely that the force needed to buckle the hinges is ever exerted under normal usage. Short column structures have a high tolerance for buckling.

3. Load analysis has demonstrated that a load of 150 psi. is needed to cause the table tops to flex (flexural stress) under a maximum load of 100 lbs. Therefore, under the worst conditions, the table top will resist a bending force of 150 psi. which is far greater than the estimated load. The table top is the controlling factor on any failure due to loading.

SELECTED REFERENCES

R. Garrison. Special Needs Housing. Home and Design, July, 1984.

I. Granet. Strength of Materials for Engineering Technolo Concepts of Stress and Strain, 1973.

M. Helander. The Video Display Terminal Design Handbook. Canyon Research Group, Inc., June 1982.

R. Hibbeler. Engineering Mechanics:Statics. Macmillan Publishing Co., Inc., 1978.

J. Makower. Office Furniture That Fits. Usair, 1983.

J. Panero and M. Zelnick. Human Dimension and Interior Space: A Source Book of Design Reference Standards, 1979.

C. Ramsey and H. Sleeper. Architectural Graphic Standards. General Planning and Design, 1970.

J. Saltman and J. Chasin. The Wheelchair in The Kitchen. Cabinet Design, Mar. 1984.

A. Yeaman. Microcomputer Learning Stations and Student Health and Safety: Planning, Evaluation and Revision of Physical Arrangements. Educational Technology, Dec. 1983.

APPENDIXES

APPENDIX 1
TOOLS NEEDED FOR PRODUCTION

1. Band saw - used for cutting curves
2. Radial arm or table saw - used for cutting straight lines
3. Jointer / planer - used to level off the high spots on the surface of the wood
4. Belt disk sander - used for smoothing exterior corners
5. Bench or floor type drill press - used for producing accurate holes
6. Wood bits/assorted - used to produce pilot holes for wood screws and for adjustments holes
7. Wood vise - used for holding wood for drilling and final finishing
8. Adjustable wrench - used to tighten nut of stove bolts
9. Phillips / regular blade screwdrivers - used to drive flat head wood screws
10. Hack saw / metal blade - used to cut off extra length of stove bolts
11. Metal file - used to smooth the cut end of the stove bolts

APPENDIX 2
WOOD MATERIALS NEEDED FOR PRODUCTION

Measurements	Size	Type	# of Pieces
160 inches/length	1" x 2"	Red Oak	1
152 inches/length	1" x 1"	Red Oak	1
48 inches x 22 inches	3/8 "	Red Oak	1
40 inches x 24 inches	1"	Red Oak	2
16 inches x 16 inches	1"	Red Oak	2
22 inches x 13 inches	1"	Red Oak	2
24 inches x 48 inches	1"	Red Oak	1
18 inches x 48 inches	1"	Red Oak	1

* This is a total of 3.50 cu.ft. of red oak.

APPENDIX J
HARDWARE NEEDED FOR PRODUCTION

Size	Description	Quantity
1 1/4 inch	finishing nails	50
2 inch x 1/2 inch	flat head wood screw	22
16 ounces	Aliphatic resin/glue	1
2 1/2 inch x 3/8 inch	stove bolt	2
3/8 inch	flat washer	2
3/8 inch	lock washer	2
3/8 inch	hexagon nut	2
Medium to extra fine	sandpaper	1 pkg
Triple 0	steel wool	1 pkg
1/2 gallon	polyurethane	1
1/2 gallon	stain (optional)	1

APPENDIX 4
ESTIMATED COST FOR PRODUCTION

Hardware - Description - Quantity	Cost
1 1/4 inch - finishing nails - 50 pieces	0.89
2 inch x 1/2 inch - flat head wood screw - 22 pieces	2.49
16 ounces - Aliphatic resin/glue - 1 container	4.29
2 1/2 inch x 3/8 inch - stove bolt - 2 pieces	0.98
3/8 inch - flat washer - 2 pieces	0.08
3/8 inch - lock washer - 2 pieces	0.09
3/8 inch - hexagon nut - 2 pieces	0.09
Medium to extra fine - sandpaper - 1 package	1.59
Triple 0 - steel wool - 1 package	1.99
1/2 gallon - polyurethane - 1 container	17.98
1/2 gallon - stain (optional) - 1 container	17.98
Sub Total of hardware costs -	$ 48.45

APPENDIX 4
ESTIMATED COST FOR PRODUCTION

Wood - Description - Quantity	Cost
160 inches/length - 1" x 2" - Red Oak - 1 piece	11.93
152 inches/length - 1" x 1" - Red Oak - 1 piece	5.66
48 inches x 22 inches - 3/8 " - Red Oak - 1 piece	36.06
40 inches x 24 inches - 1" - Red Oak - 2 pieces	71.56
16 inches x 16 inches - 1" - Red Oak - 2 pieces	19.08
22 inches x 13 inches - 1" - Red Oak - 2 pieces	21.32
24 inches x 48 inches - 1" - Red Oak - 1 piece	42.93
18 inches x 48 inches - 1" - Red Oak - 1 piece	32.20
Sub Total of wood costs -	$ 240.74
Total cost of materials -	$ 289.74

APPENDIX 5
PRODUCTION TIME

The time necessary for production is decided on three factors. The first factor is the availability of materials. The second factor is the availability of the correct tools needed for production. The last factor is the degree of skill and knowledge of the builder in the use of the tools and working with the medium of wood. Taking into account the aforementioned factors, it is estimated that a skilled builder can construct a finished product in 8 hours. This estimation considers only the builder's time and not the time for finishing, staining, or allowing the glue to dry.

SHOP DRAWINGS

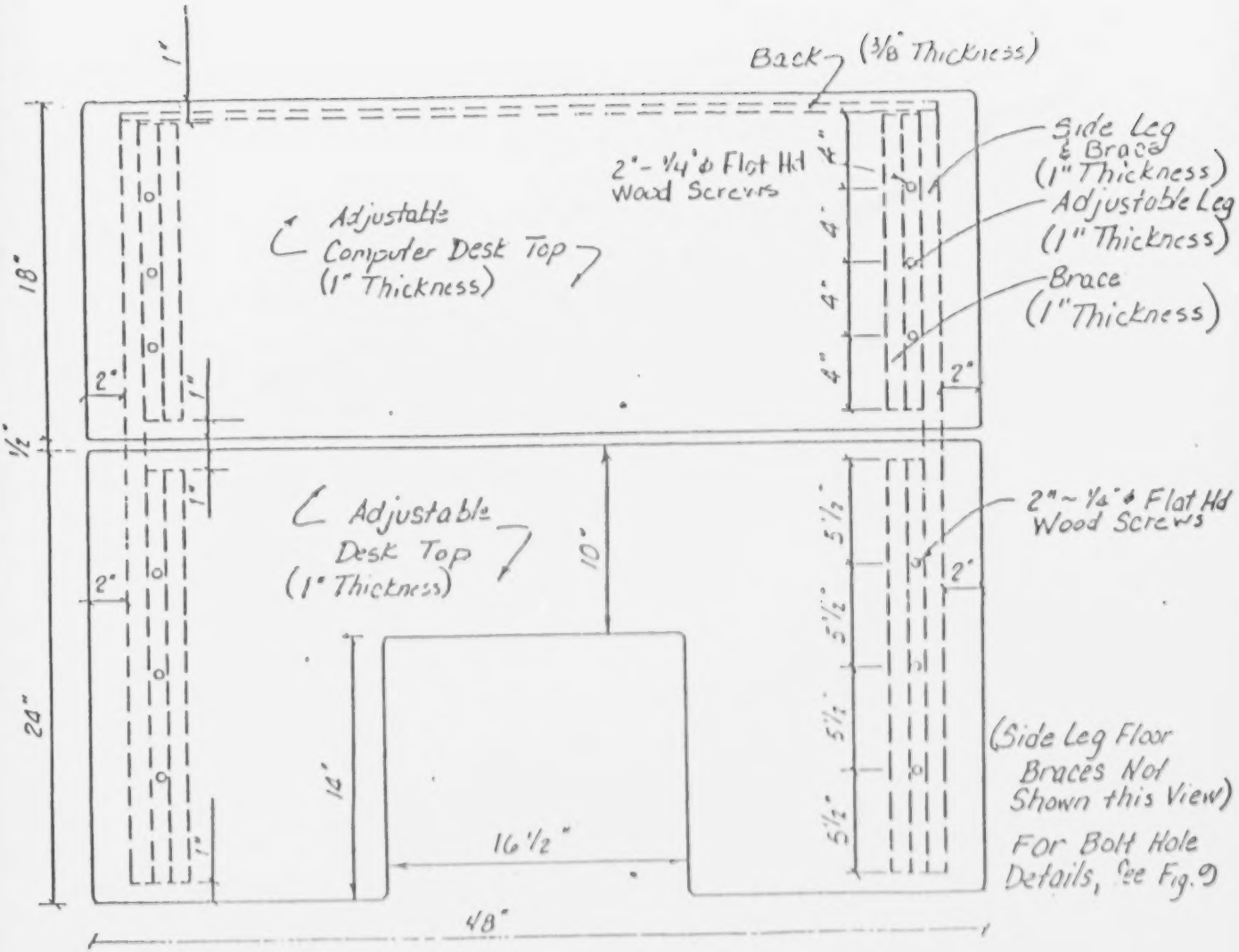


FIGURE 7 - TOP VIEW
1/8" = 1"

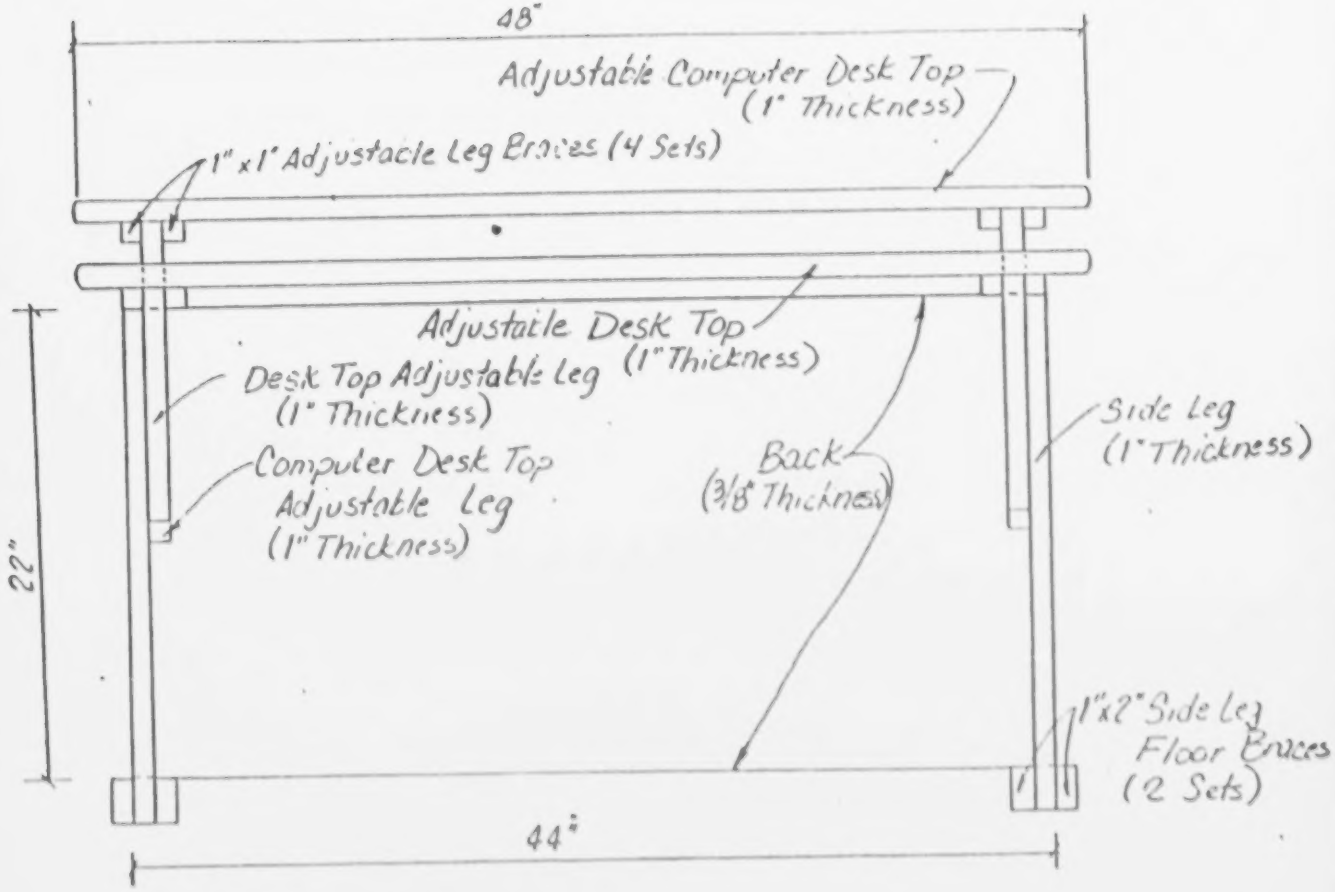


FIGURE 8
FRONT VIEW - 1/8" = 1"
(Shown Standard Position -- Computer Desk Top 3" Above Desk Top)
Bolt Holes Not Shown, See Details

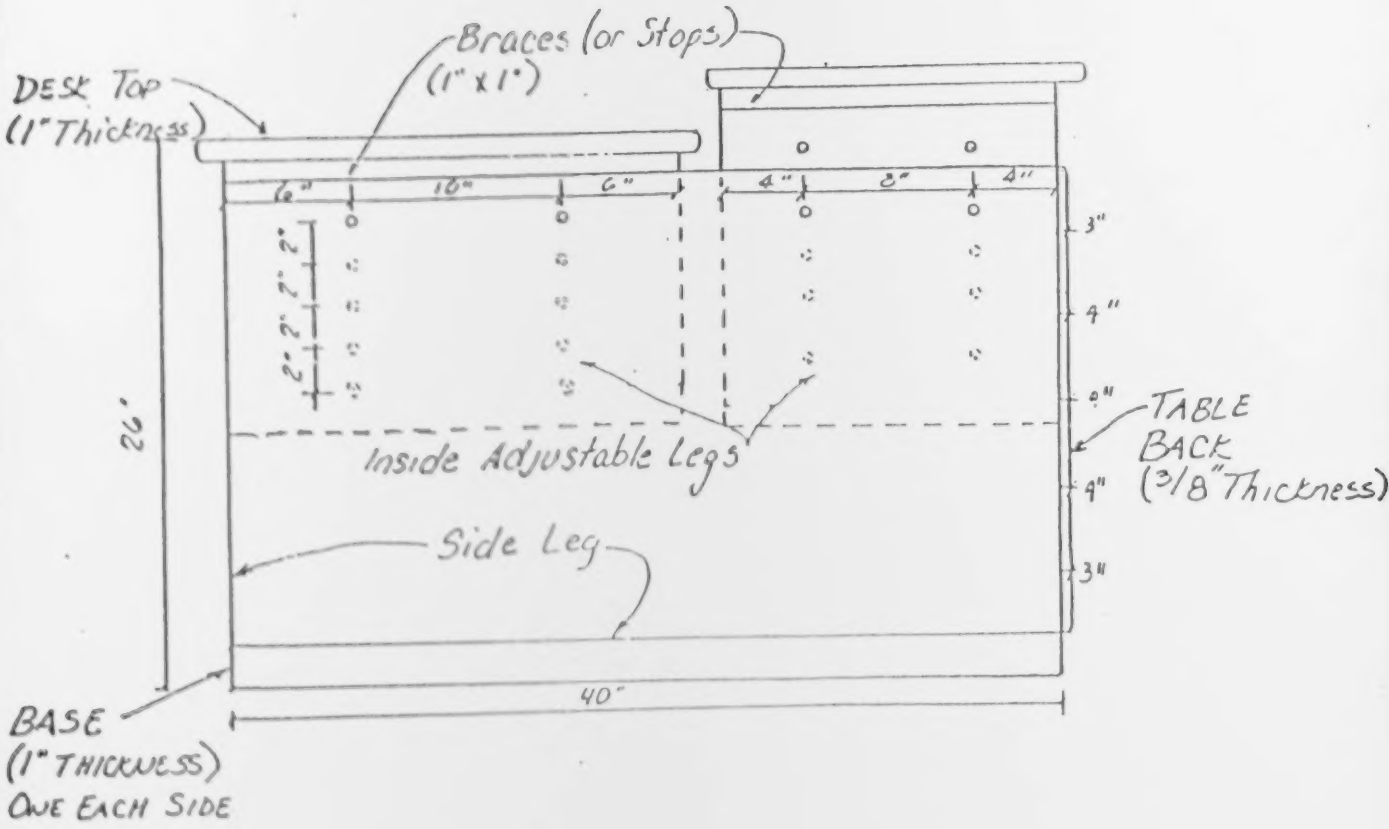


FIGURE 9
SIDE VIEW (LEFT & RIGHT)
1/8" = 1"

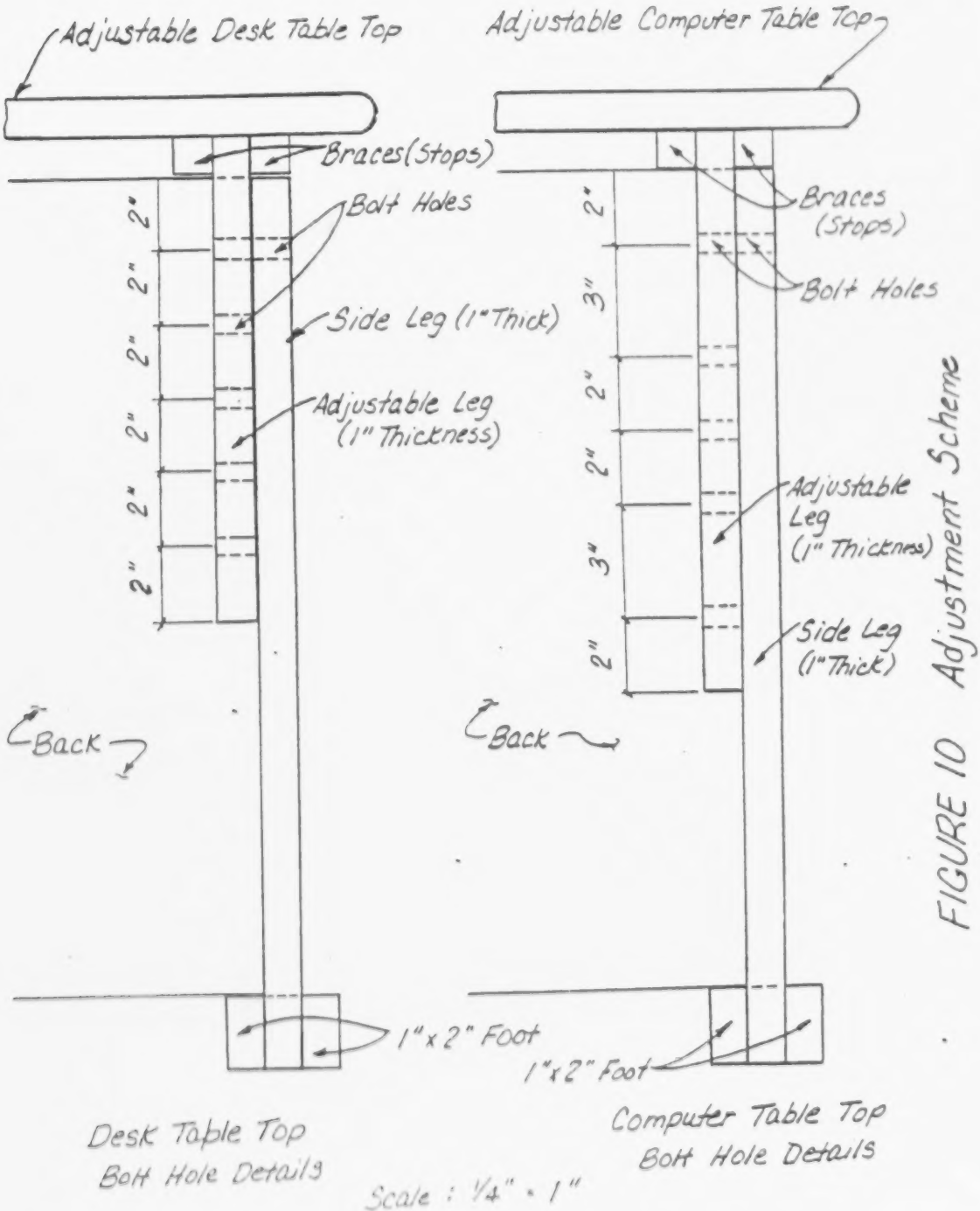


FIGURE 10 Adjustment Scheme